FPGA-Based Integer Echo State Networks in E-Health

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Introduction

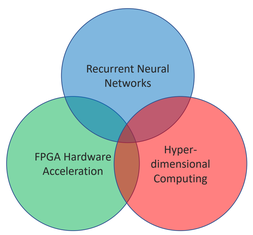
Electronic health (e-health) is becoming more and more prevalent, especially with the emergence of new technologies in telecommunication, computer vision, and artificial intelligence. Some technical challenges and limitations are hindering the feasibility and practicality of Information and Communication Technologies (ICT) integrations into the health domain.

- Training and using Neural Networks require tremendous amounts of memory and computation power [1]
  intESNs have a lower memory and computational footprint
  FPGAs can make the computations more efficient and faster
- Cloud Computing was not meant for the Internet of Things (IoT) [2]
  FPGAs are enablers for Fog Computing

Background & Context

The core work of this research draws from three distinct areas of computer science:

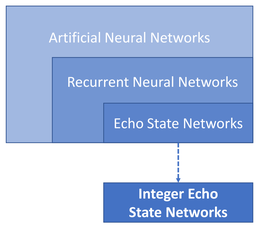
(1) Recurrent Neural Networks
(2) Hyperdimensional Computing
(3) FPGA Hardware acceleration

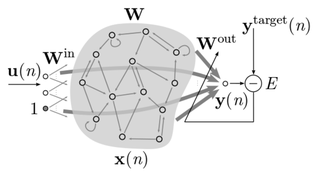


In addition, it uses E-Health as a potential area of application and showcases some scenarios and the benefits of following the presented approach.

Integer Echo State Networks (intESN)

Integer Echo State Networks (intESN) have a similar architecture to Echo State Networks (ESN), except that some of the reservoir manipulation operations are optimized, and use integer instead of floating point operations; making them more efficient in terms of both memory and computational complexity for performing the same tasks [3, 4].





Hyperdimensional Computing (HDC)

Hyperdimensional Computing (HDC) is a computing framework that uses hyper-dimensional vectors instead of conventional computing units (e.g. 10,000 bits instead of 32).
Mathematical properties arise from such a representation, and using basic logic (i.e. arithmetic) operations one can compose higher-level complex concepts and operate in a similar fashion to human cognitive reasoning [5].

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What is the dollar of Mexico?

        A = X*U + Y*D
        B = X*M + Y*P

Z = (D*A)*B = P + Noise ≈ P
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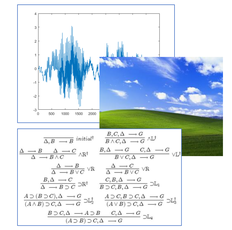
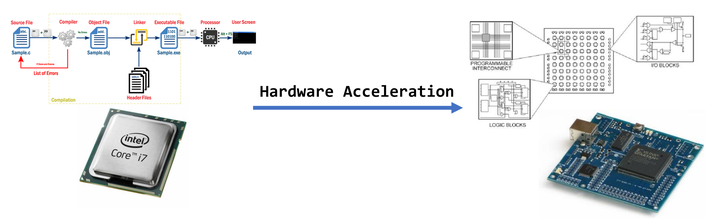


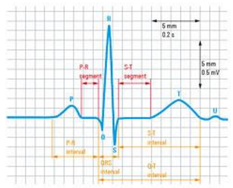
FPGA Hardware Acceleration (HA)



Hardware Acceleration (HA) is the process of converting a piece of software that runs on a general purpose CPU into specific code to run on a target higher-end processing device such as a GPU, or directly run at the hardware-level such as FPGAs and dedicated ASIC chips. Generally, it results in a much higher throughput and efficient resource utilization [6].

E-Health + Electrocardiography (ECG)

E-Health is the process of using ICT to enhance medical processes such as: computer aided diagnosis, computer communication tools for patients/doctors, bio-information trackers… etc.
Electrocardiographic (ECG or EKG) reports provide information about heartbeat characteristics, and IT could be used in the diagnosis process in classifying ECG signals and identifying anomalies [7].



SWOT Analysis of the Proposed Solution

Strengths
- Power efficiency
- E-Health benefits
- Promote sustainable behavior

Weaknesses
- Introduction of new hardware
- Might be considered not useful

Opportunities
- Enabler for Fog Computing
- New applications in e-Health

Threats
- Automation
- Dehumanizing a critical process

Research Goals

- Implement an efficient intESN architecture for FPGA
- Measure its performance (e.g. memory use, energy consumption, throughput… etc.) as compared to traditional PC and GPU implementations
- Evaluate the benefits and feasibility of such systems in the context of Fog Computing
- Showcase a potential application in e-Health (e.g. ECG analysis)

Future Work

- Make intESN even more efficient using binarization and/or linear integer programming approaches for optimization problems
- Investigate parallels between HDC and Binarized Neural Networks (BNNs), and reconcile Neural-Symbolic Reasoning with Connectionist AI Models

Meta

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references